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COMPARATIVE ANALYSIS OF THE PROCESSES FOR MACHINING OF MOLD ELEMENT WITH USING TOPSOLID'CAM AND ESPRIT

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ABSTRACT

In the present article has been proposed route for design of mold element with using TopSolid, and developed comparative analysis of the technological processes for machining of element of a mold with using TopSolid'CAM and ESPRIT, as covering all basic operations for 3-axis machining of design surfaces. Experimental studies are realized on a machining center DMG MORI NVX 5060. The results are illustrated in tabular and graphical form.

Key words: CAD/CAM systems, TopSolid'CAM, ESPRIT, High-speed milling, Molds, Cutting Tools, Cutting conditions

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1. INTRODUCTION

Object of design in this paper is a comparative analysis of technological processes for machining of element from mold.

High-speed machining of materials is associated primarily with carrying milling operations and use of machining centers [16]. Typical of this type of machining is the greater speed of rotation of the spindle, which aims to achieve better results in materials handling, higher quality at a relatively high performance.

One of the most developed areas of the use of CAM system is the design of technological process and generate NC (Numerical control) program for CNC machines. Of extreme importance for production planning is to coordinate its various individual stages. An essential role in this process play a Computer Aided systems whose interaction and integration support highly modern engineering [3,4].

2. DESIGN OF A MOLD ELEMENT WITH USING TOPSOLID

The design is carried out in an environment of system TopSolid. The main stages are associated with the process of production and run in the following sequence:

- loading file;
- sizing and formatting;
- shaping operations;
- boolean operations;
- technological and propagation operations.

2.1. Loading file that contains the 3D model of the Part – fig. 1,a. [2,11,13]

2.2. Sizing and formatting

Activates the absolute coordinate system. Parallel to the X axis is drawn a line coming out of the contours of the workpiece, which is the distance from X axis of 287, 5mm – fig.1,b

By using the Trim operation is done cutting the workpiece. Performed using the tool to cut a curve (BY SWEEPING CURVE). Give the base element and the curve as that will be done cutting. It turns the direction of the cutting – fig.1,c.

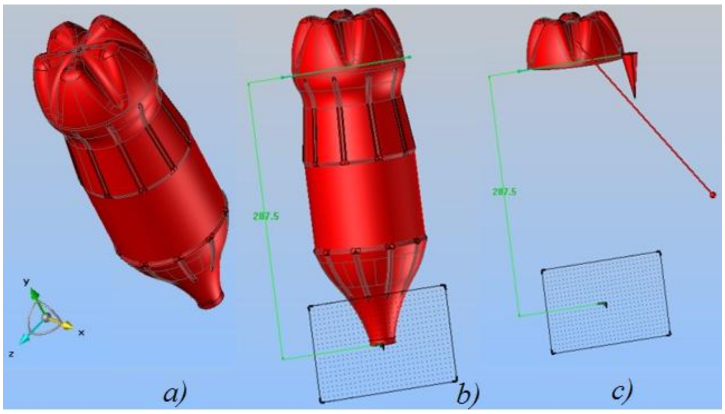


Figure 1 Sizing and formatting [11,13]:

a) loading file; b) creates the absolute coordinate system; c) cut a curve

2.3. Shaping operations

By Extrude operation, received a new face is extended by 15mm - fig.2,a. On the same person define a new coordinate system (Coordinate system by face), then draws a square with a size of side 50mm. The square is located symmetrically to the coordinate system – fig.2,b.

Design of three-dimensional object from the contour of the base - square by operation Create extruded shape, size 30mm – fig. 2,c.

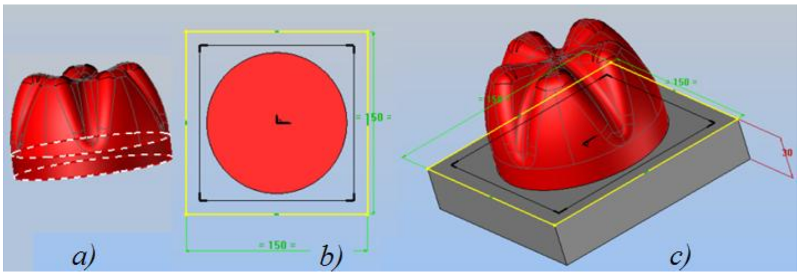


Figure 2 Shaping operations:

a) extrude operation; b) creating sketch; c) creating a third dimension

2.4. Boolean operations

Available two bodies come together in a Boolean operation by Unite, indicating primary and secondary units – fig.3,a.

2.5. Technological and propagation operations

Drilling operation - drilling a hole with countersunk located at a distance from one corner 20x20 - fig.3,b.

Propagation of hole, by using double mirror - fig.3,c.

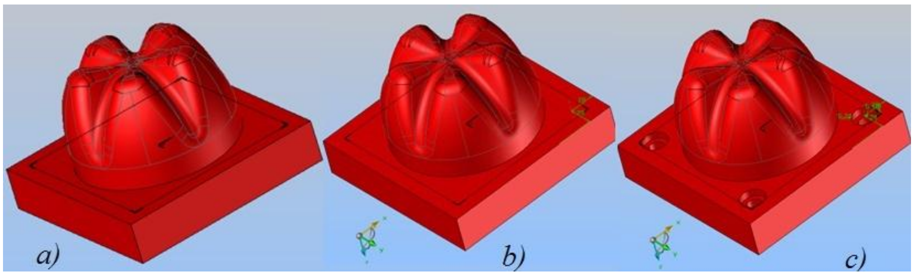


Figure 3 Technological and propagation operations:

a) Unite operation; b) drilling; c) propagation - double mirror

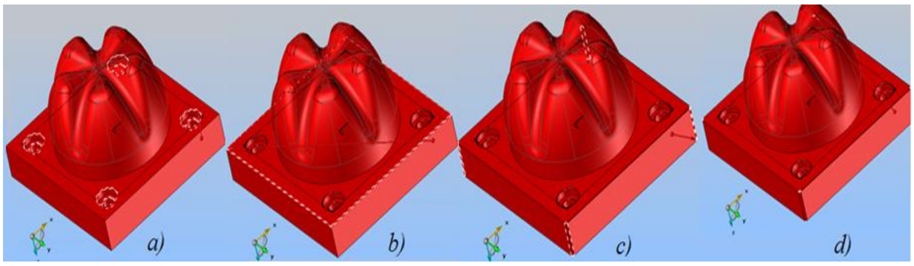


Figure 4 Shaping the chamfers

Shaping the chamfers:

- $0,5x45^{o}$ on the upper edges of countersunk – fig.4,a;
- $0,5x45^{o}$ on the edges of upper face – fig.4,b;
- $2x45^{o}$ on the lateral edges – fig.4,c;
- $0,5x45^{o}$ on the lateral edges – fig.4,d;

3. COMPARATIVE ANALYSIS OF TECHNOLOGICAL PROCESSES REALIZED BY TOPSOLID'S CAM AND ESPRIT

The production of element of a mold begins with the design, which is done using CAD software. To be written control program for 3-axis milling machine used CAM software [9, 10].

Viewing is a detail of the structure of the mold. In designed element are complex profile surfaces. According geometry follows that the production of this configuration will need application of milling operations.

According to the application of the workpiece all surfaces must be made with roughness Ra 0.32. It follows that all surfaces must be clean processing and then polished.

The quality of the technical assignment using specified CAD model [11, 13]. Carried out an analysis of the technology's design aimed locating errors in the geometry of the model. It was found that CAD model is suitable for use in a CAM environment [8]. This process is designed to perform a comparative analysis between the two CAM software. Therefore been chosen machines, tools and devices from databases TopSolid'CAM and ESPRIT.

3.1. Choice of machines, tools and equipments

Milling processes are executed on the machine DMG MORI NVX 5060 – fig.5,a [16].

Tools [15]:

- Facing Mill (Roughing) - End Face Mill 50/ D_c50/ $l_1$16.5 – фиг.5,b
- Slot Mill (Re-Roughing) - FR_2TAL-016060Z-SA50/ Dc16/ $l_1$63 – фиг.5,c
- Slot Mill (Facing Spiral) - FR_2TAL-016060Z-SA50/ Dc16/ $l_1$63
- Slot Mill (Roughing) - FR_2TAL-008030Z-SA50/ Dc8/ $l_1$38
- Pure milling – BALL NOSE MILL FR-008050R-SA50/ D_c8/ $l_1$38 – фиг.5,d.

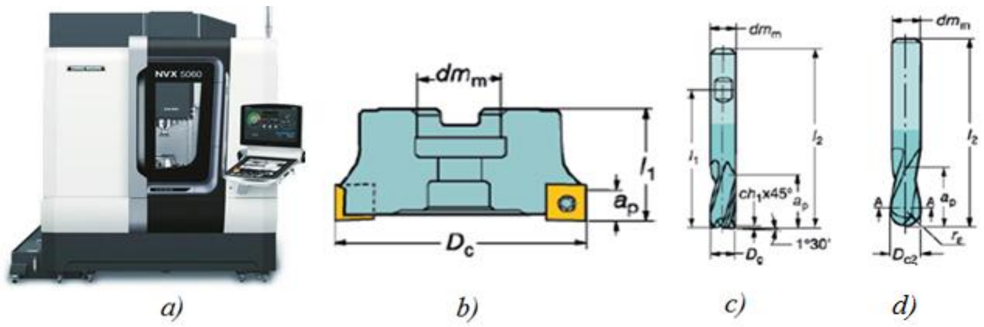


Figure 5 Machines, tools and equipments:

a) DMG MORI NVX 5060; b),c), d) types of cutting tools

3.2 The calculation of processing additives and intermediate sizes

On the working drawings to detail is applied to the final dimensions and tolerances that match finish machining operations. It is therefore necessary to calculate intermediate additives.

Intermediate size, that is the amount received by any coherent transition (surgery) for the treatment of a surface layer and the metal necessary for the performance of individual transitions is called solutions [1,5].

By solving dimensional chain, which is formed by the size of the piece, intermediate additions and size of the workpiece can be certain all dimensions of technological process for machining. For the calculation of the intermediate sizes is necessary prior to calculate intermediate additives. The latter can be done by two methods: analytical and tabular. Since the final dimensions of the workpiece are used to output data, intermediate sizes are calculated in order, the opposite of the performance of process, i.e. starting from the last transition and come to the first [1,5].

The size of the smallest additives [1,5] is defined as:

- sequentially machining of opposing and spaced apart surfaces [1,5]

$$Z_{min} = R_{zi(i-1)} + D_{(i-1)} + \rho_{(i-1)} + \Delta_{yi} \quad (1)$$

- simultaneously machining of the opposite faces

$$2Z_{min} = 2(R_{zi(i-1)} + D_{(i-1)} + \rho_{(i-1)} + \Delta_{yi}) \quad (2)$$

- machining of external and internal rotation surfaces

$$2Z_{min} = 2(R_{zi(i-1)} + D_{(i-1)} + \sqrt{\rho_{(i-1)}{}^{2} + \Delta_{yi}{}^{2}}) \quad (3)$$

where:

- Z_{min} - is the smallest addition of a country considered a technological transition,
- $R_{zi(i-1)}$- is the height of the roughness obtained after the previous transitions,
- $D_{(i-1)}$ - defective layer of the material obtained after the previous transitions,
- $\rho_{(i-1)}$ - are the spatial variations of the workpiece after the previous transitions,
- Δ_{yi} - is error form establishment.

3.3 The calculation of cutting conditions

Calculation of the cutting conditions is performed by the system using methods developed in tabular method. Depths of cut are determined in accordance with the intermediate size and additives for processing. Feeds are also derived from the system [1,5,6]. Permissible cutting speed Vc [m/min] Fixes for each transition depending on the material of the cutting plate processed material, depth of cut and feed, as tabular values are corrected with corrections coefficients [7].

3.4 Determination of machining time

Machining time for manufacturing of detail is defined as [6]:

$$T_C = \sum_{i=1}^{n} \frac{L_j}{S_{M\,j}}.i_j\,, \mathrm{min} \quad (4)$$

where:

- L_j - the length of the course for the j-th transition, min,
- S_{Mj} - minute submission of the j-th transition
- i_j - number of the course for the j-th transition,
- n - number of the course for operation.

3.5 Technological operations - TopSolid'CAM [12]

For the design of operations in CAM environment, workpiece and the final product have the same geometry, fig.6.

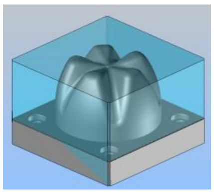
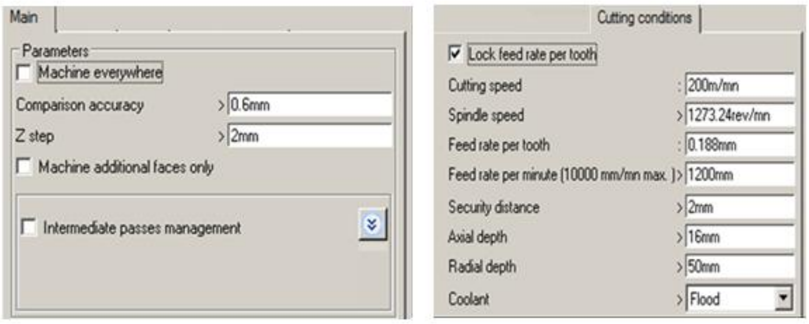


Figure 6 Workpiece and final product

I Roughing

Table 1 TopSolid'CAM - I Operation - Parameters



Main	
Parameters	
☐ Machine everywhere	
Comparison accuracy	0.6mm
Z step	2mm
☐ Machine additional faces only	
☐ Intermediate passes management	

Cutting conditions	
☑ Lock feed rate per tooth	
Cutting speed	200m/mn
Spindle speed	1273.24rev/mn
Feed rate per tooth	0.188mm
Feed rate per minute (10000 mm/mn max.)	1200mm
Security distance	2mm
Axial depth	16mm
Radial depth	50mm
Coolant	Flood

The trajectory of the tool for I Operation with TopSolid'CAM is presented in fig.7,a Machining Time Tc = 29:32 min.

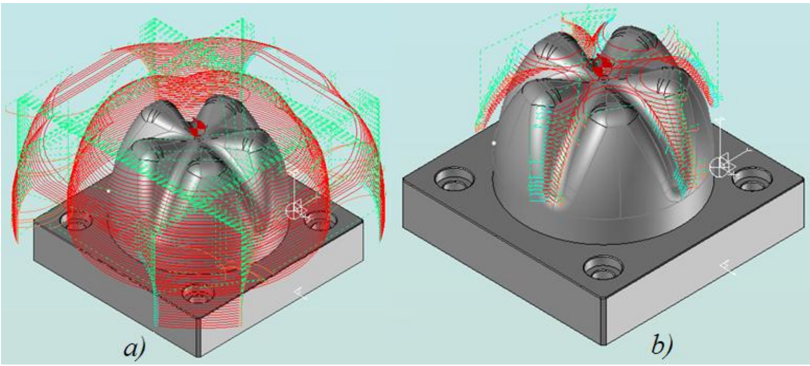
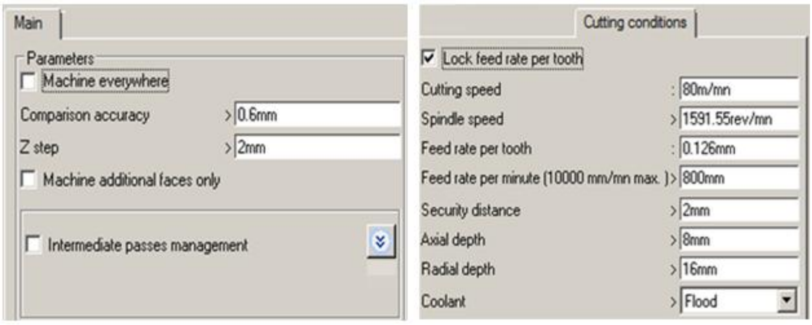


Figure 7 Trajectory of the Tool:

I Operation, b) II Operation

II Re-Roughing

Table 2 TopSolid'CAM - II Operation - Parameters



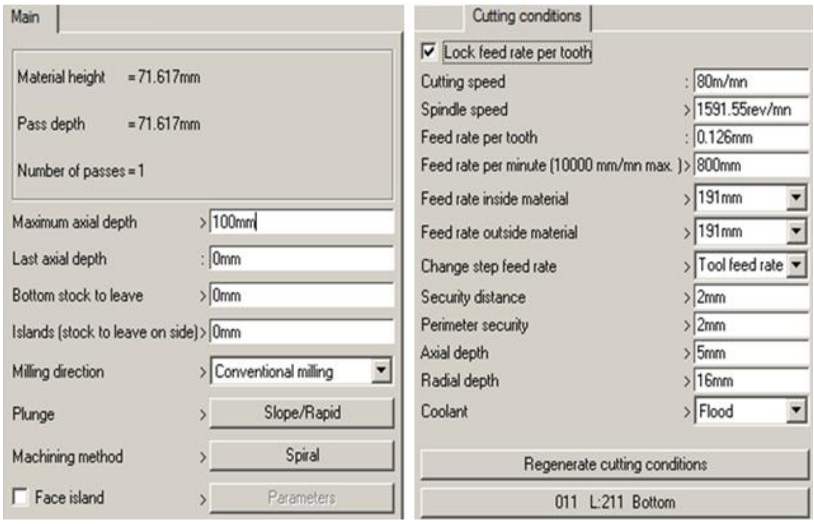
Main	
Parameters	
☐ Machine everywhere	
Comparison accuracy	0.6mm
Z step	2mm
☐ Machine additional faces only	
☐ Intermediate passes management	

Cutting conditions	
☑ Lock feed rate per tooth	
Cutting speed	80m/mn
Spindle speed	1591.55rev/mn
Feed rate per tooth	0.126mm
Feed rate per minute (10000 mm/mn max.)	800mm
Security distance	2mm
Axial depth	8mm
Radial depth	16mm
Coolant	Flood

The trajectory of the tool for II Operation with TopSolid'CAM is presented in fig.7,b. Machining Time Tc = 05:05 min.

III Facing spiral

Table 3 TopSolid'CAM - III Operation - Parameters



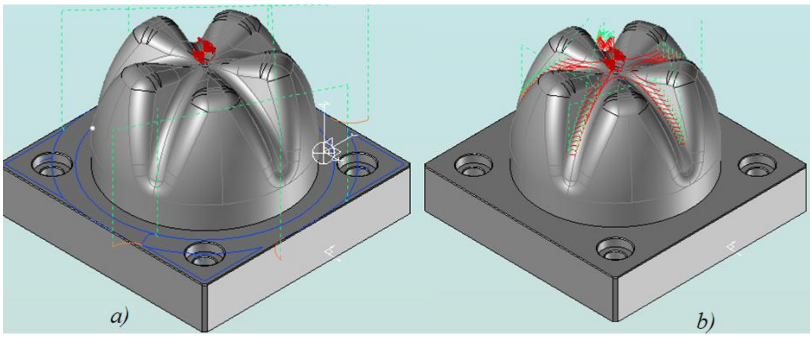


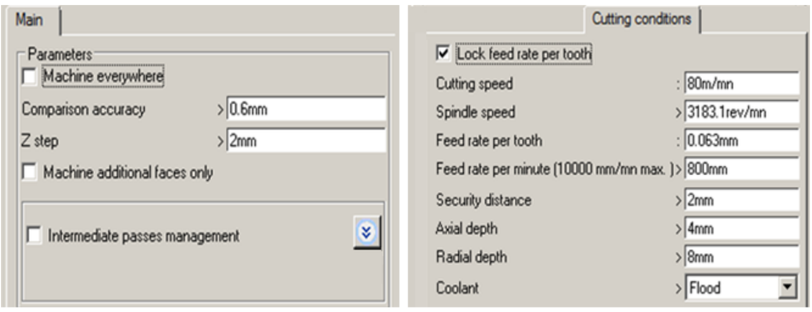
Figure 8 Trajectory of the Tool:

III Operation, b) IV Operation

The trajectory of the tool for III Operation with TopSolid'CAM is presented in fig.8,a. Machining Time Tc = 02:09 min.

IV Roughing

Table 4 TopSolid'CAM - IV Operation - Parameters



The trajectory of the tool for IV Operation with TopSolid'CAM is presented in fig.8,b. Machining Time Tc = 01:54 min.

V 3D automatic operation Pure Milling

Table 5 TopSolid'CAM - V Operation - Parameters

Main – Parameters	
Scallop height	0.005mm
Step over	0.282mm
3D overlap	0mm
Undercut management	No undercut
First projection	Along Z axis
Dist.Max. between pts	10mm

Cutting conditions	
Lock feed rate per tooth	☑
Cutting speed	100m/mn
Spindle speed	3978.87rev/mn
Feed rate per tooth	0.101mm
Feed rate per minute (10000 mm/mn max.)	800mm
Security distance	2mm
Axial depth	1mm
Radial depth	2mm
Coolant	Flood
Others cutting conditions	

The trajectory of the tool for V Operation with TopSolid'CAM is presented in fig.9,a. Machining Time Tc = 90:08 min.

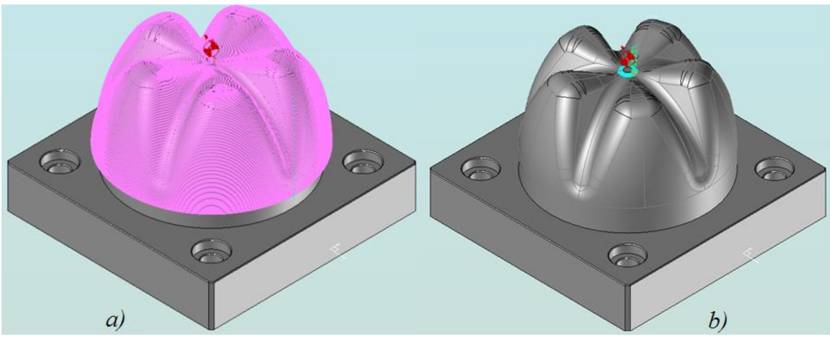


Figure 9 Trajectory of the Tool:

III Operation, b) IV Operation

VI Finely Milling

Table 6 TopSolid'CAM - VI Operation - Parameters

Parameters	
Offset	0mm
Tol./Curve	0.005mm
Step	0.198mm
Scallop height	0.0098mm
Dist.Max. between pts	0.1mm
Minimal toolpath length	100mm

Cut. cond	
Lock feed rate per tooth	☑
Cutting speed	80m/mn
Spindle speed	12732.4rev/mn
Feed rate per tooth	0.059mm
Feed rate per minute (10000 mm/mn max.)	1500mm
Security distance	2mm
Axial depth	1mm
Radial depth	0.5mm
Coolant	Flood

The trajectory of the tool for VI Operation with TopSolid'CAM is presented in fig.9,b. Machining Time Tc = 00:29 min.

3.6 Technological operations – ESPRIT [12]

The trajectory of the tool for I, II and III Operation with ESPRIT is presented in fig.10,a,b,c. For IV, V and VI ESPRIT operation in fig. fig.11,a,b,c.

Operations types are the same with TopSolid. They will not be presented operation – parameters, and only machining time – Table 7.

Table 7 ESPRIT - machining time

Operations	I	II	III	IV	V	VI	Total
T_c [min]	24:08	06:48	01:57	04:47	123:55	00:11	161,9

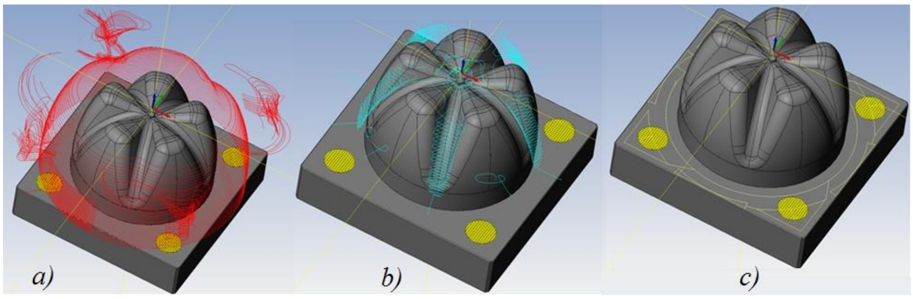


Figure 10 Trajectory of the Tool with ESPRIT:

I Operation, b) II Operation,c) III Operation

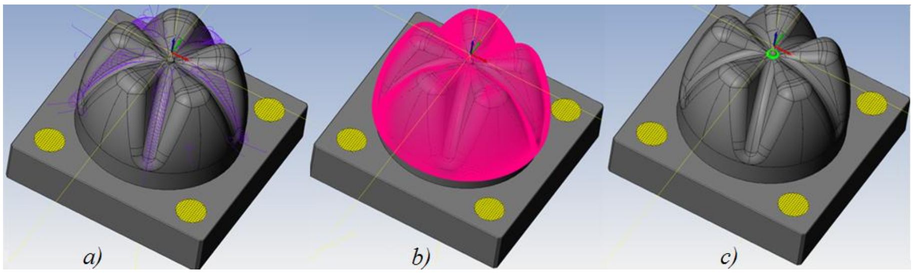


Figure 11 Trajectory of the Tool with ESPRIT:

a) IV Operation, b) V Operation,c) VI Operation

3.7 Comparative analysis of machine times in the implementation of both technological route.

The data are shown in fig.12. It is evident that the programming with TopSolid'CAM cumulative machine time is 129,12min, and in ESPRIT 161,9min. This clearly shows higher performance in the implementation of the first route compared to the second.

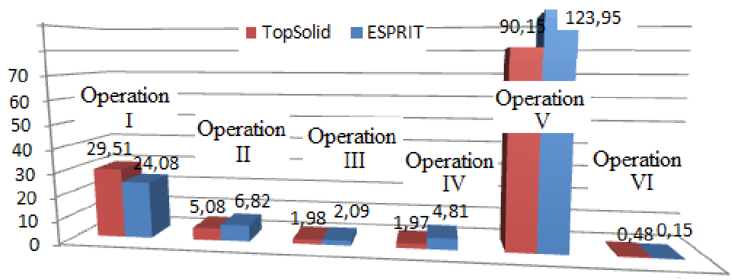


Figure 12 Time-operating diagram

4. CONCLUSION

4.1 Developed and proposed a route for design of mold element with using TopSolid.

4.2 Developed comparative analysis of the technological processes for machining of element of a mold with using TopSolid'CAM and ESPRIT, as covering all basic operations for 3-axis machining of design surfaces.

4.3 Operations are described in the CAM environment for two routes, as are defined additives, cutting conditions and machining time.

4.4 The total machining time by TopSolid'CAM is 129.12min and, in the ESPRIT 161.9min, i.e. with 20.24% larger.

4.5 The analysis shows higher performance at the same indicators of quality, concerning the machining of detail with such a configuration in the programming environment TopSolid'CAM, compared with ESPRIT.

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